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Recent Literature on Water Quality in Colchester, Vermont: A Part of the Strategic Water Quality Planning Process

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1. INTRODUCTION

This document has been prepared as part of the Strategic Water Quality Plan development process for the Town of Colchester, Vermont. The Strategic Water Quality Plan is being spearheaded by the Department of Public Works in coordination with the Water Quality Committee and other members of the public, and it will include priorities for maintaining and improving the quality of Colchester's water resources.

This report is intended to be a quick guide to what is known in the literature from the previous five to ten years about water resources and water quality in Colchester, and it is written to be accessible to those with no previous training in water quality evaluation. It presents basic information on water resources, degradation of their quality, and recommendations for future policy.

The next section presents water resources in Colchester identified in the literature consulted. The following section, Section 3, discusses impairments to or issues with those water resources. Section 4 shows the human impacts on the water resources—the causes of the impairments identified in the previous section—and Section 5 compiles various recommendations that have been made to improve water quality. There is an appendix with annotations for the most significant studies consulted.

2. WATER RESOURCES

Surface water is highly significant in Colchester. The Town of Colchester has an area of 37.0 square miles (Center for Rural Studies 1998) and about thirty miles of shoreline on Lake Champlain. The shores of Malletts Bay nearly surround almost ten square miles of the lake (Town of Colchester Vermont 2001). Its southern border has about nine miles of frontage on the Winooski River, and the northwestern border has about three miles of frontage on the Lamoille River. Numerous streams and wetlands are also in the town.

On the large scale, all watercourses flowing through Colchester ultimately arrive in Lake Champlain, which flows into the Atlantic Ocean at the Gulf of St. Lawrence, via the Richelieu River in Quebec and the St. Lawrence River. On a smaller scale, a recent report (Griffin International 2002) identifies 35 subwatersheds in Colchester and classifies them as discharging into one of five destinations (Figure 1, Table 1): Lake Champlain (broad lake), Winooski River, Lamoille River, outer Malletts Bay, and inner Malletts Bay. By this classification, most of the town's area and nineteen of the town's thirty five subwatersheds drain into inner Malletts Bay, with the Winooski River receiving much of the rest.

Eight of the watersheds extend outside of town, and this includes many of the watersheds emptying into inner Malletts Bay. The major ones are: Allen Brook, Malletts Creek, Pond Brook, Indian Brook, and Sunderland Brook. Most of the water in the Lamoille and Winooski Rivers also originates upstream of Colchester.

Inland from Lake Champlain, 186-acre Colchester Pond is the major open water body. The pond is the result of a dam, and it has been used as potable water supply in the past. Most of its shoreline is pasture and undeveloped woodland. Vermont's Fisheries Biologist says that the pond has excellent pike and bass fishing, based on anglers' surveys, and in 2002 has been described in Vermont Outdoors magazine as a "premier northern pike fishery" (Vermont Department of Environmental Conservation 2002). It is designated a Class A2 watersupply for the Village of Colchester and, though not used since 1974, it is reserved for emergency purposes (Vermont Department of Environmental Conservation 2002).

Wetlands form significant other water resources. The National Wetland Inventory identifies 165 wetlands, ranging in size up to 458 acres, with 3066 acres total in wetlands (National Wetland Inventory n.d.). These are designated as Class Two wetlands, that is, they are "significant and merit protection" under the Vermont Wetland Rules. In addition, there are many unmapped Class III wetlands (Soboslai, pers. comm.)

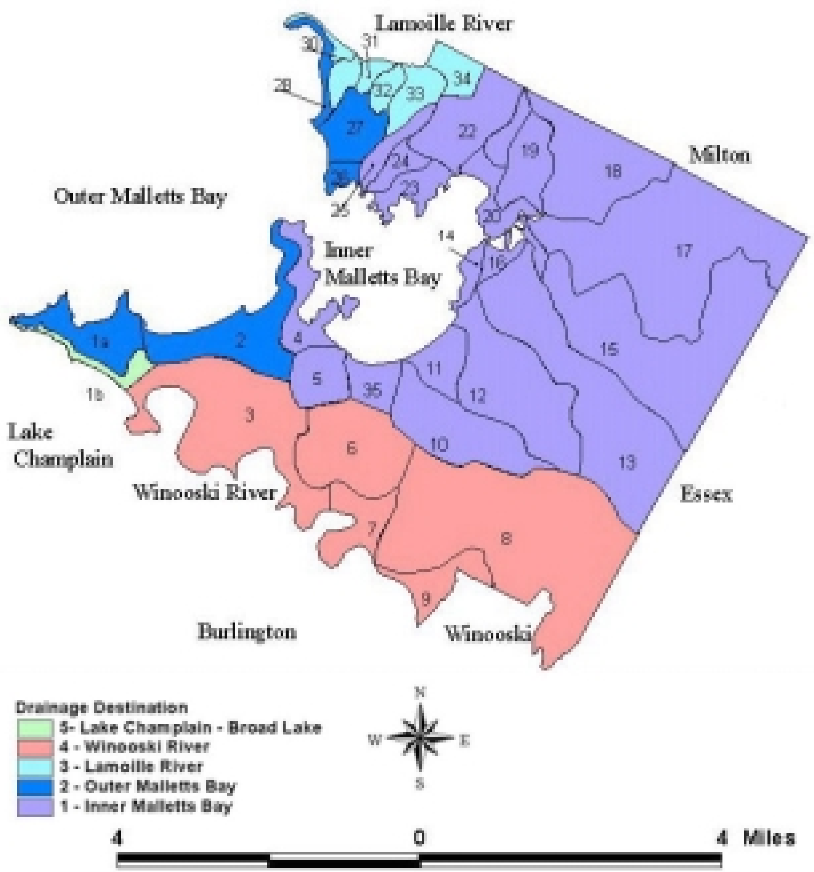

Figure 1. Subwatersheds in Colchester, grouped by destination. Source: (Griffin International 2002)

Watershed number	Watershed name	Area (acres)*	Destination
1a	Colchester Point North	486.	Outer Malletts Bay
1b	Colchester Point South	179.	Lake Champlain (broad lake)
2	Malletts Head West	850.	Outer Malletts Bay
3	Halfmoon Cove	173.3	Winooski River
4	Malletts Head East	405.	Inner Malletts Bay
5	Diversity Hill	20.2	Inner Malletts Bay
6	Shipman Hill	16.	Winooski River
7	Pine Island	3.2	Winooski River
8	Sunderland Brook	327.1	Winooski River
9	Winooski West	29.1	Winooski River
10	Smith Hollow Stream	890.	Inner Malletts Bay
11	Lake Shore Drive	293.	Inner Malletts Bay
12	Crooked Creek	56.8	Inner Malletts Bay
13	Indian Brook	166.1	Inner Malletts Bay
14	Malletts Bay Point East	118.	Inner Malletts Bay
15	Pond Brook	151.	Inner Malletts Bay
16	Interstate 89	7.3	Inner Malletts Bay
17	Malletts Creek	51.1	Inner Malletts Bay
18	Allen Brook	29.5	Inner Malletts Bay
19	Chimney Corner	28.3	Inner Malletts Bay
20	Interstate 89 North	14.8	Inner Malletts Bay
21	Chimney Corner West	150.	Inner Malletts Bay
22	Walnut Ledge East	647.	Inner Malletts Bay
23	Braeloach Camp	9.6	Inner Malletts Bay
24	Braeloach Camp West	153.	Inner Malletts Bay
25	Red Rock East	184.	Inner Malletts Bay
26	Red Rock Point	94.	Outer Malletts Bay
27	Camp Norfleet	18.2	Outer Malletts Bay
28	Wissiquam Orchard	0.9	Outer Malletts Bay
29	Camp Kiniya	3.4	Lamoille River
30	Camp Kiniya North	61.	Lamoille River
31	Winnisquam Orchard East	81.	Lamoille River
32	Camp Norfleet East	120.	Lamoille River
33	Walnut Ledge	13.8	Lamoille River
34	Walnut Ledge North	184.	Lamoille River
35	Malletts Bay	38.7	Inner Malletts Bay
* indicates area contained within Town of Colchester			

Table 1. Subwatersheds in Colchester and their area, Colchester, Vermont. Source: (Griffin International 2002)

Many of these have the potential to be designated a Class One wetland (i.e., “exceptional or irreplaceable in [its] contribution to Vermont’s natural heritage” (Water Resources Board 2001)), but Class One status requires that someone petition the State, and no one has done so for Colchester’s wetlands (Moulaert, pers. comm.). Table 2 shows the “priority wetlands,” that is, those “with high functional significance and with moderate to high threats of future degradation,” which the Vermont Department of Environmental Conservation (1997) has identified in Colchester.

TABLE 2. PRIORITY WETLANDS IN COLCHESTER, VERMONT

Wetland	Area (acres)	Rare/ threatened bird species	Rare/ threatened fish species	Rare/ threatened plant species	Natural communities	Recommendations
Sandbar, Lamoille River Delta	1700[1]	X		X	"[O]ne of the impressive floodplain forests in Vermont"[2]	"Because of its exceptional quality, the floodplain forest at the Lamoille delta merits special protection and recognition within the state lands as an ecological reserve or natural area. It should be excluded from all timber harvest and protected from other environmentally degrading human activities such as river control structures."[2]
Malletts Creek Marsh (west of Munson Flats and east of Malletts Bay)	425	Likely	X	X	"[G]ood examples of deep rush marsh, floodplain forest, and red maple swamp"[3]	Little fieldwork done; "natural communities should be defined and mapped, and both plants and animals need a more complete survey."[3] "This wetland could be severely degraded in a relatively short time due to development in the adjacent buffer areas. The Fish and Wildlife Department, which owns [20 acres], should acquire the remaining wetland acreage and acquire conservation easements or management leases on the wet meadows to protect adequate northern pike spawning sites."[4]
Colchester Point Rush Meadow (north shore of tip of Colchester Point)	1			X	"[G]ood example of an uncommon lakeshore grass/rush meadow"[3]	

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Wetland	Area (acres)	Rare/ threatened bird species	Rare/ threatened fish species	Rare/ threatened plant species	Natural communities	Recommendations
Colchester Bog (On Colchester Point, between Mills and Porter Points, intersected by railroad bed)	150			X	"[O]ne of two large peat bogs...along the shores of Lake Champlain"[3]	Because suburban housing is encroaching on adjacent land, the owners (UVM) should consider purchasing adjacent parcels as a buffer, if they come up for sale.[3]
Delta Park (Winooski Delta)	75	X		X	"[A] unique and productive ecosystem" with "good examples of the following...communities: lakeshore grassland, lakeshore sand beach, deep rush marsh, and cattail marsh."[3]	The Northshore Wetland in Burlington "is part of the same delta and should be included in the Delta Park site."[3]
Half Moon Cove (west of Rt. 127, immediately north of highway bridge across the Winooski River)	275[5]			X	"A-ranked examples of lakeside floodplain forest and riverine floodplain forest (silver maple-ostrich fern type)."[2] "Important site for wildlife, especially lake fish (spawning area) and waterfowl (both as nesting area and migratory stopover)."[3]	"Derway Island and Halfmoon Cove should be considered a single ecological system...[T]hese sites should be protected as conservation lands of the highest quality."[2]

TABLE 2. PRIORITY WETLANDS IN COLCHESTER, VERMONT

Wetland	Area (acres)	Rare/ threatened bird species	Rare/ threatened fish species	Rare/ threatened plant species	Natural communities	Recommendations
Pine Island Shrub Swamp (next to Winooski River, south of WVMT studios and north of Pine Island)	375				"Extensive and mostly undisturbed shallow shrub swamp...[with] important habitat for wildlife—birds as well as aquatic animals."[3]	"A policy of no development should be adopted for the Pine Island Shrub Swamp."[3]
School #4 Wetland (West of Prim Road and south of Lakeshore Drive)	100				Hardwood/cedar, seasonally flooded. Land use has highly degraded the wetland, but it still has moderate levels of: flood storage, recreation, wildlife, water purification, open space[6]	"Current landowners should be made aware of its Class Two status and protection so that there is no further encroachment; buffers should be clearly delineated and maintained."[6]
Rosetti Wetland and Beach (on lakeshore, east of Holy Cross Camp)	15			X	"Buttonbush swamp and maple/ash forest with emergent wetland and open water"[6]	Increase the buffer zone to 100 feet.[6]
Indian Brook Corridor	Narrow band 4.5 miles long			good potential[6]	Riverine system of shrub and emergent communities. "[P]otential for major wildlife corridors...with a wide range of animal life."[6]	"Zoning should consider increasing the buffer to 100' and should carefully examine proposals that require further road crossings or cutting or mowing of brookside vegetation."[6]

TABLE 2. PRIORITY WETLANDS IN COLCHESTER, VERMONT						
Wetland	**Area (acres)**	**Rare/ threatened bird species**	**Rare/ threatened fish species**	**Rare/ threatened plant species**	**Natural communities**	Recommendations
Sunderland Brook mouth and wetland complex	4 miles along entire length of brook				Riverine wetland system of shrub and emergent communities. Two silver maple floodplain forests at mouth. "[P]otential as important wildlife habitat."[6]	The Town should consider zoning that would extend the buffer along the course of the brook to 100', measured from the top of the bank, in order to protect it as a corridor. The property on the military reservations should be required to adhere to wetland regulations...The floodplain at the mouth...has the potential to be an excellent site for...wetland restoration if it is taken out of agricultural use. The functions of the floodplain forest would be enhanced if logging was kept to a minimum."[6]
Niquette Bay wetland and beach	25				"Bayside emergent marsh and shrubland extending inland into a maple/ash swamp"[6]	"Property owners should be made aware of wetland regulations and buffer zones should be maintained...Any requests for upgrading of the beach homes should be considered in light of possible direct and indirect wetland impacts."[6]

1. Primarily in Milton
2. (Sorenson et al. 1998)
3. (Vermont Fish and Wildlife Department 1992)
4. (Binhammer 1994)
5. The latest delineation (Department of Environmental Conservation 1997) reports 260 acres but has not corrected the total acreage for its inclusion of 15 acres east of the 127 bridge.
6. (Department of Environmental Conservation 1997)

Table 2. Priority wetlands in Colchester, Vermont

3. DEGRADATION IN WATER QUALITY

Many of the studies consulted focus on water quality issues in Colchester. Here, water quality is discussed in terms of three hydrogeographic areas: outer Malletts Bay, inner Malletts Bay, and the rivers, streams, and large pond inland from Lake Champlain. Degradation, i.e., diminished quality, in these areas are described below.

3.1. Outer Malletts Bay

3.1.1. Nutrients

Phosphorus has been identified as a major degrading factor in Lake Champlain (Smeltzer and Quinn 1996), (Lake Champlain Basin Program 2002). Phosphorus is a nutrient which, in overabundance, can lead to undesired algae blooms, hypoxia (lack of oxygen) in bottom waters, and change of plant and animal species distribution, composition, and abundance. According to the Lake Champlain Basin Program (1998), Malletts Bay is near but not over the goal set for it: the average total phosphorus concentration is 9.8 parts per billion (ppb), while the goal is 10 ppb or less. However, the input to Malletts Bay is still greater than target levels set for maintaining under 10 ppb phosphorus. Phosphorus loads to Malletts Bay dropped from 32.9 metric tons per year (mt/year) in 1991 to 29.7 mt/year in 1995, the latest year for which data are available (Lake Champlain Basin Program 2002). This is still 1.1 mt/year over the target. Furthermore, "based on the 2000 LCBP report of the Phosphorus Reduction Task Force, it appears that phosphorus loads generated by land use changes in the Basin are offsetting some of the gains achieved by point and nonpoint source reduction efforts. As the population within the Basin increases, more land is becoming developed. Because developed land generates more phosphorus than other land uses, nonpoint source phosphorus loads may be increasing in parts of the Basin where the land use change is occurring" (Lake Champlain Basin Program 2002).

3.1.2. Toxins

In Lake Champlain in general, mercury appears in such high amounts that the Vermont Department of Health has issued an advisory suggesting strict limits on consumption of fish from the lake: "The Vermont Department of Health advises that people should eat not more than one meal per month of walleye...and six meals per month of all other fish caught in Vermont state waters. Women of child-bearing age and children under 6 are advised to not eat any walleye...and limit consumption of all other fish caught in Vermont state waters to two meals per month" (Lake Champlain Basin Program 2000). Because pollution from PCBs in Lake Champlain adds to the toxicity from mercury, the Department of Health advisory for lake trout from Champlain is stricter than for other waters (Bress 2002). The Department of Health advises that “[a]dults should limit their consumption of lake trout (over 25 inches) caught in Lake Champlain to one meal per month, and women of childbearing age and children under 15 should not eat any lake trout from Lake Champlain” (Lake Champlain Basin Program 2000).

The upper layer of lake bottom sediments in outer Malletts Bay is contaminated with arsenic, manganese, and nickel. A Lake Champlain Basin Program technical report (McIntosh, Watzin, and Brown 1997) concluded, “Concentrations of As [arsenic], Mn [manganese], and Ni [nickel] in the surface sediments of Outer Malletts Bay exceeded either the NOAA [National Oceanographic and Atmospheric Administration] ER-M [Effects Range-Medium; contamination greater than the ER-M value indicates adverse benthic impacts in more than 50% of cases studied] or the Province of Ontario SEL [Severe Effects Level; concentrations above the SEL are predicted to cause adverse effects to bottom-dwelling organisms] at many sites, but especially at the deepest locations.” In addition, concentrations of arsenic and magnesium are high enough that the report recommends careful evaluation of the water quality before using outer Malletts Bay water as a drinking water source. Finally, the zebra mussel infestation has the potential for increasing problems related to sediment toxicity, as the mussels can mobilize more of elements bound in sediment.

Malletts Bay is on the Department of Environmental Conservation’s Part A list of 303(d) waters, those which require a Total Maximum Daily Load plan, for mercury and PCBs found in the fish. Because of arsenic, manganese, and nickel in the sediments, Malletts Bay is on the Department of Environmental Conservation’s Part C list of waters which may require a Total Maximum Daily Load plan if further investigation shows them to be in violation of water quality laws (Water Quality Division 2002b).

3.1.3. Invasive Species

Further degradations of Lake Champlain which affect Malletts Bay include the invasive species sea lamprey (*Petromyzon marinus*), zebra mussel (*Dreissena polymorpha*), and Eurasion milfoil (*Myriophyllum spicatum*). Lampreys have been identified as threats to the lake’s native lake trout and salmon fisheries and its introduced rainbow (steelhead) trout fishery. An eight-year program to control lampreys resulted in a significant reduction in the scars from lampreys, and the Fisheries Technical Committee of the Lake Champlain Fish and Wildlife Management Cooperative recommended the program continue (Nashett et al. 1999). Zebra mussels are small mollusks whose dense growth encrusts solid objects and allows them to outcompete native mussels. They have had an impact on native mussel populations in outer Malletts Bay (Water Quality Division 2002b).

Eurasion milfoil is a highly invasive and aggressive aquatic plant which outcompetes native plants and clogs waterways with its dense growth. The Vermont Department of Environmental Conservation has identified a Eurasion milfoil infestation in Malletts Bay, but notes that weevils, which can control the milfoil, are present in Lake Champlain (Water Quality Division 2002b). The Town's Master Plan says that Eurasian milfoil is "present but not pervasive" (Town of Colchester Vermont 2001).

3.1.4. Other

Muskellenge and northern pike in Lake Champlain have fallen victim in increasing numbers to what appears to be a viral disease, esocid lymphosarcoma, which produces large tumors. The Vermont Department of Fish and Wildlife has warned fishermen not to eat fish with tumors. This is termed a precautionary measure; no human health effects are known from eating infected fish (Associated Press 2002).

3.2. Inner Malletts Bay

Degradations affecting outer Malletts Bay also affect inner Malletts Bay. (However, much less is known about sediment contamination in inner Malletts Bay, as the study consulted (McIntosh, Watzin, and Brown 1997) had only one sampling location in all of the inner bay.) In addition, the waters of inner Malletts Bay are affected by pathogen contamination near the shore, which may cause swimmers to become ill. The Town of Colchester has been taking water quality samples, mostly at outlets to tributaries and at recreational areas, during the summer for over ten years. The annual reports on these data are a rich source of information on Malletts Bay water quality. Many of the sites sampled have fecal coliform and/or *E. coli* densities greater than Vermont state safety limits for recreactional waters. (The current standard is 77 MPN *E. coli*/100 ml; MPN stands for Most Probably Number and refers to the number of bacteria which are capable of forming colonies under specified conditions in the laboratory.) Table 3 shows figures for some "hot spots" during eight years of sampling (Gabos 2000); the author comments, "This is a rough method of comparison, since the exact location a sample is taken will change from year to year and within the year, depending on height of the lake and flow in streams."

Sample site	1991	1992	1993	1994	1995	1998	1999	2000	Avg. %
The Moorings Stream	30	31	35	42	92	19	27	31	38
Smith Hollow Stream	11	23	75	88	71	69	96	68	69
60 Lakeshore Dr. Stream	na	25	15	5	32	25	23	21	21
28 Lakeshore Dr. Stream	11	46	25	10	39	50	23	55	32
Crooked Creek	60	23	65	64	52	38	100	90	61

Table 3. Percentage of summer sample dates on which fecal coliform and/or *E. coli* densities exceeded Vermont state safety limits for recreational waters, for selected sampling spots in inner Malletts Bay. Source: (Gabos 2000)

Before the 2001 summer season, a baffle box to catch stormwater sediment was installed in the stream at The Moorings marina. In 2001, the percentage of samples for which state *E. coli* limits for recreational waters were exceeded at that spot dropped to 17% (4 out of 24), much lower than the average in Table 3 of 38% and somewhat lower than the previously recorded low of 19% (Foley 2001). The low rainfall in 2001 may have played a role in the reducation, as well.

In 2001, a study was performed to find a connection between wind and *E. coli* levels high enough to lead to beach closings (Foley 2001). No correlation was found.

E. coli and fecal coliform bacteria are indicator organisms, so they do not directly translate into information about pathogens coming from humans or those which are capable of infecting humans. Identifying the species from which *E. coli* bacteria come from helps indicate to what extent they may be correlated with human pathogens, and it also gives a clue as to what sort of control measures are likely to bring about reduced E. coli levels. To identify the origin of bacteria found in Malletts Bay and the Winooski River, a microbial source tracking study was undertaken in 2001 (Jones 2002). A process called DNA ribotyping was used to determine what species the *E. coli* sampled had originated from.

The DNA of *E. coli* found in water samples from Malletts Bay and the lower Winooski was compared with that from *E. coli* taken from the feces of a number of mammal species in the areas—seagulls, raccoons, cats, cows, mallards, and humans (septic tank and wastewater treatment plant samples). This emerging technology gave limited results, with only 28% of the 176 *E. coli* which were found successfully matched with a host species, even at the lowest threshold of similarity used to identify a positive match (80%).

For the thirty isolates successfully matched in Colchester, deer were the most frequently identified host species, with six isolates; i.e., six *E. coli* bacteria from all the water samples were matched with those known to originate from deer. Humans and raccoons each had five isolates. Of the samples of water draining to Malletts Bay, three of the fifteen successfully identified isolates came from humans, and of the samples of water draining to the Winooski River, two of ten successfully identified isolates came from humans. The human isolates were found in the storm drain outfall at 60 Lakeshore Drive (1), the mouth of Smith Hollow Creek (2), and Sunderland Brook at the Pines Island Road crossing (2). In addition to the human isolates, the storm drain outfall at 60 Lakeshore Drive had isolates from cat, gull, racoon, and two unknowns. Smith Hollow Creek had isolates from cat, coyote, deer, mallards, and raccoon, with one unknown. Sunderland Brook had isolates from chicken and muskrat, with seven unknowns.

Jones explains that there is no basis in the data or the literature to speculate on what the distribution of unknowns might be (pers. comm.). In other words, while the data indicate that a number of organisms are contributing to E. coli counts in Colchester's waters, 72% of the *E. coli* found were not successfully matched to any host organism, so a large degree of uncertainty about the magnitude of any organism's contribution remains.

3.3. Rivers, Streams, and Colchester Pond

While the Lamoille River contributes a large quantity of water to outer Malletts Bay and the Winooski River drains and borders a significant fraction of Colchester, most of the water in the rivers comes from upstream of Colchester. Colchester can do relatively little to influence water quality in the rivers, so relatively little effort was put into finding studies on the river water quality. More effort was put into finding information on the streams and Colchester Pond.

3.3.1. Winooski River

The Winooski River conveys a large load of phosphorus to the broad lake of Lake Champlain, 83.8 metric tons in 1991. Vermont's Department of Environmental Conservation (DEC) has identified a mercury impairment in the lower 6.5 miles of the river (Water Quality Division 2002a) and put this section of the river on the 303(d) Part A list (impaired waters, for which a Total Maximum Daily Load plan must be developed).

3.3.2. Lamoille River

The Lamoille River carries nearly all of the phosphorus load to Malletts Bay. In 19991, a total of 32.9 metric tons of phosphorus was transported to Malletts Bay (Lake Champlain Basin Program 2002), and 29.6 metric tons of this total was transported by the Lamoille River (Water Quality Division 2002b). Vermont's DEC has identified a possible nutrient impairment at the mouth of the river and put the mouth of the river on the 303(d) Part C list. Designation on the Part C list means that the river will be included in the next 303(d) list (Part A: Impaired Waters) if assessment results show it to be in violation of water quality standards.

Vermont's Department of Environmental Conservation (DEC) has identified a mercury impairment in the lower 6.5 miles of the river (Water Quality Division 2002a) and put this section of the river on the 303(d) Part A list.

The DEC has also identified the lower Lamoille River as possibly impaired (303(d) Part C) for swimming by high levels of pathogens, possibly coming from failing septic systems. Dams on the lower Lamoille lead to an "artificial and poor flow regime [which] impairs all uses," according the DEC (Water Quality Division 2002b).

The Lamoille River is also a primary contributor of trace metals to Malletts Bay, concluded a report on sediment toxins (McIntosh, Watzin, and Brown 1997). While the report did not attempt to quantify the present contribution of the Lamoille River, the studies found high levels of arsenic and other metals at the mouth of the Lamoille, where they had presumably come from upstream sources like surface mines and mine tailings piles, atmospheric deposition, and erosion of soils and rocks.

3.3.3. Streams

The Vermont Department of Environmental Conservation has issued a report card on the water quality in Colchester's streams, using measures of biological integrity, including counts of insects, other aquatic invertebrates, and fish. The latest results are given in Table 4.

A collection of small streams called "direct smaller drainages to inner Malletts Bay" have been placed on the 303(d) Part A list for *E. coli* levels. Indian Brook is on the Part A list from the lake upstream 9.8 miles to Butlers Corner, because of its poor biological condition and habitat degradation. The length of Sunderland Brooks is on the Part A list for toxins and undefined pollutants. Morehouse Brook is currently on the Part A list but has been suggested for delisting, as stormwater management plans are in place (Water Quality Division, 2002a).

In addition, the DEC has found a number of possible impairments in Indian Brook, Malletts Creek, and "direct small drainages leading to Malletts Bay;" all of these are on the 303(d) Part C list (Water Quality Division 2002b).

Stream/% of Watershed Impervious	Site	Nutrient Index	Clean Water Species	Insect Diversity	Insect Density	Insect Community Assessment	Fish Community Assessment
Allen Brook	Above	No data	No data	No data	No data	No data	No data
% 3.0*	Below	**E**	**P**	**G**	**918**	Passes	Passes
Indian Brook	Above	**VG**	**F**	**E**	**1098**	Passes	Fails
% 6.3	Below	**E**	**P**	**G**	**2532**	Fails	Passes
Malletts Creek	Above	**G**	**G**	**F**	**444**	Fails	Fails
% 2.0*	Below	**VG**	**VG**	**E**	**1642**	Passes	No data
Morehouse Brook	Above	**E**	**P**	**F**	**969**	Fails	No data
% 13.6	Below	**E**	**P**	**P**	**133**	Fails	No data
Colchester Pond	Above	No data	No data	No data	No data	No data	No data
%7.0*	Below	**G**	**P**	**VG**	**1016**	Fails	Passes
Sunderland Brook	Above	**G**	**P**	**F**	**1638**	Fails	Fails
% 11.4	Below	**F**	**P**	**P**	**34**	Fails	Passes

* Measurement only includes area within Colchester town line

Table 4. Vermont Department of Environmental Conservation's water quality report for Colchester. E = Excellent VG = Very Good G = Good F = Fair P = Poor An upward (blue), downward (red), or not apparent (yellow) trend in water quality is indicated where three or more years of data exist. "Above" refers to the upstream sample station and "below" refers to the downstream station; exact locations are not specified. Source: (Vermont Department of Environmental Conservation, n.d.)

In Malletts Creek, possible pollutants include nutrients at the mouth and, for 3.5 miles upstream, sediments, nutrient and organic enrichment, and pathogens. The possible pollutants are listed as land development, erosion/sedimentation, and urban runoff, with a note that the creek delivers 1.7 metric tons phosphorus to Malletts Bay each year.

In Indian Brook, pathogens are listed as possible pollutants, possibly originating in failed septic systems.

The direct small drainages to Malletts Bay are listed as possibly having sediment, nutrient and organic enrichment, and pathogens as pollutants, arising possibly from urban runoff and septic system failures.

3.3.4. Colchester Pond

Results from the Winooski Valley Park District (WVPD) from monitoring in 2001 show that the State *E. coli* standard for contact use of 77 MPN/100 ml was exceeded three times out of thirty one sampling events at a site at the south edge of the lake. At the southwest shore, however, closer to the visitor parking lot, the maximum value out of 39 samples was 23 MPN/100 ml. WPVD's phosphorus measurements showed the pond to be mesotrophic (medium level of nutrients), with median measurements of 18 ppb P. The Vermont Department of Environmental Conservation (DEC) designates the pond as eutrophic (high level of nutrients), based on five years of spring phosphorus readings averaging 36 ppb P. The DEC has also designated the pond's aesthetics, aquatic life, secondary contact use, and swimming uses as threatened, based on potential algal blooms and oxygen depletion in the deep water and some shoreline periphyton (attached algae) (Vermont Department of Environmental Conservation 2002). Thirty three acres of the pond are threatened by Eurasion milfoil, reports the DEC, as the pond is near an infested Lake (presumably Lake Champlain).

4. HUMAN IMPACTS ON THE WATERSHEDS

This section sketches what is known about human uses which affect the watersheds in Colchester, which may be causes of some of the impairments described above.

4.1. Drinking Water and Wastewater

In 1997, a wastewater facility plan update (Forcier Aldrich & Associates 1997) was delivered to the Town, and this also contains some information about drinking water. Geographically, much of the town is served by private water supplies (i.e., fewer than ten service connections, serving fewer than twenty five people, or operates fewer than sixty days per year) coming from groundwater (Figure 2). Much of the population, however, is served by public water distributed by Fire Districts 1-3 or directly by Champlain Water District. Fire District 2 gets their water from Burlington, which takes it from an inlet 4200 feet out from the Coast Guard station at the Burlington waterfront, in 50 feet of water (Dion, pers. comm.). Fire Districts 1 and 3 get their water from Champlain Water District, which has an intake in Shelburne Bay, in 75 feet of water, half a mile offshore (Fay, pers. comm.)

Wastewater treatment and dispersal in most areas of town are predominantly accomplished with individual, onsite systems. Exceptions include the Exit 16 area, the Route 15 area, the Breezy Acres trailer park, and Severance Corners, from which municipal wastewater is pumped to the City of South Burlington Airport Parkway Water Pollution Control Facility, on the south side of the Winooski River. Creek Farm Plaza is also in this sewer service area, but onsite systems are also in use on some properties there. The other exception is the Fort Ethan Allen Complex, where the Town of Essex' sewage collection system takes the wastewater to the Tri-Town Wastewater Treatment Facility in Village of Essex Junction.

The wastewater facility plan update divides Colchester into eleven wastewater management units, based on site suitability for onsite wastewater treatment, existence of wetlands or flooplains, type of potable water supply and distribution system, and current land use and zoning (Figure 3).

The Forcier Aldrich & Associates report concludes:

- Existing development is concentrated in areas favorable for individual onsite wastewater treatment systems.
- Many of the onsite systems in town are approaching the end of their useful life.
- Onsite systems seem to fail where site conditions are marginal.
- There is a public perception that seasonal camps' systems are polluting Malletts Bay.
- Telephone surveys have indicated that most home owners do not pump their septic tanks every four years; this can cause premature system failure.
- Onsite systems represent the lowest cost strategy in areas where soils and site conditions are favorable for it. Drinking water contamination may be minimized in areas of dense residential development by installing municipal water if there are individual wells in use for potable water.
- The user costs for centralized systems would be higher than in nearby communities, since US EPA subsidies are not available to the same extent as when those were constructed.

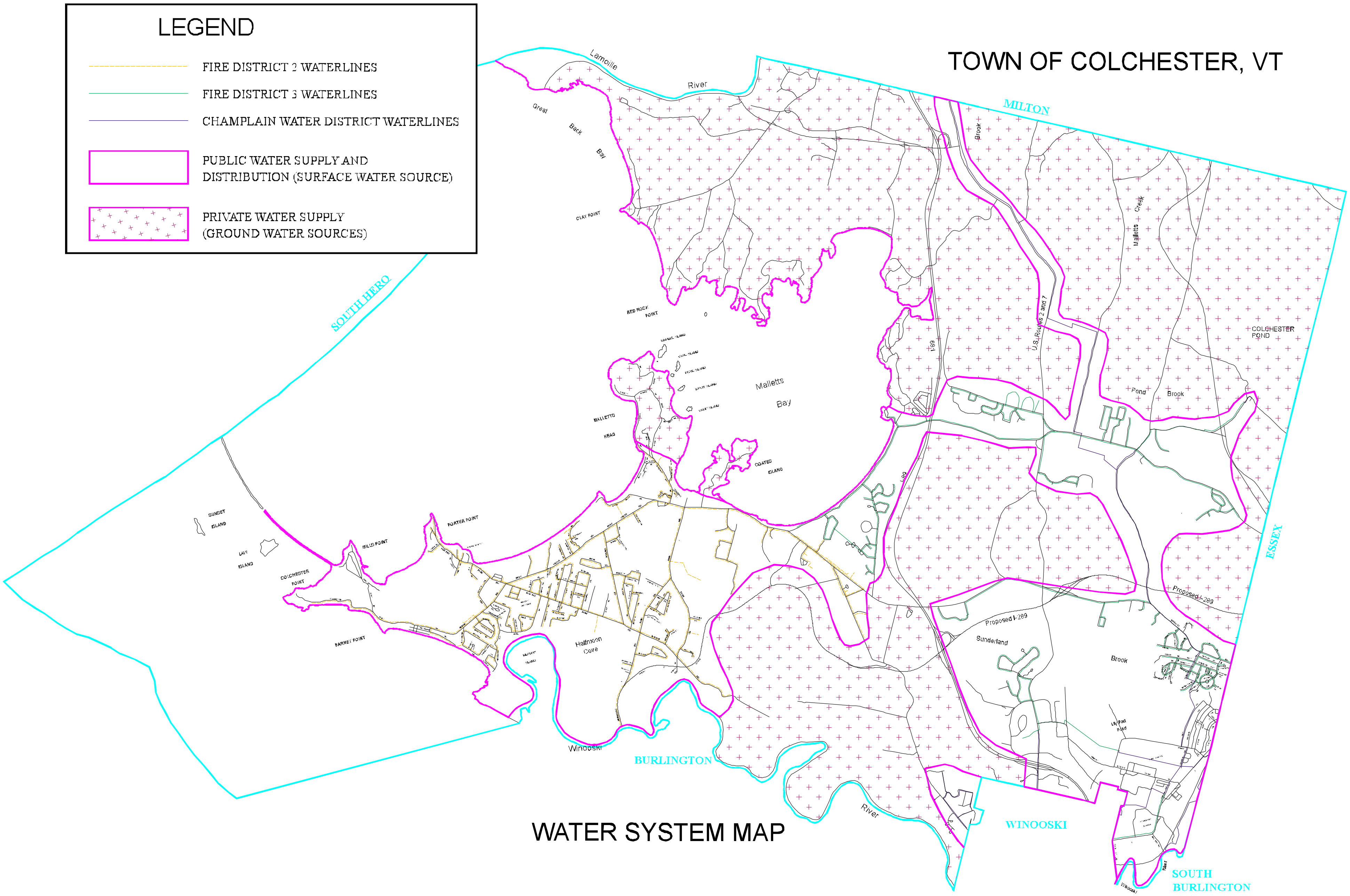

Figure 2. Drinking water supplies in Colchester. Source: (Forcier Aldrich & Associates 1997).

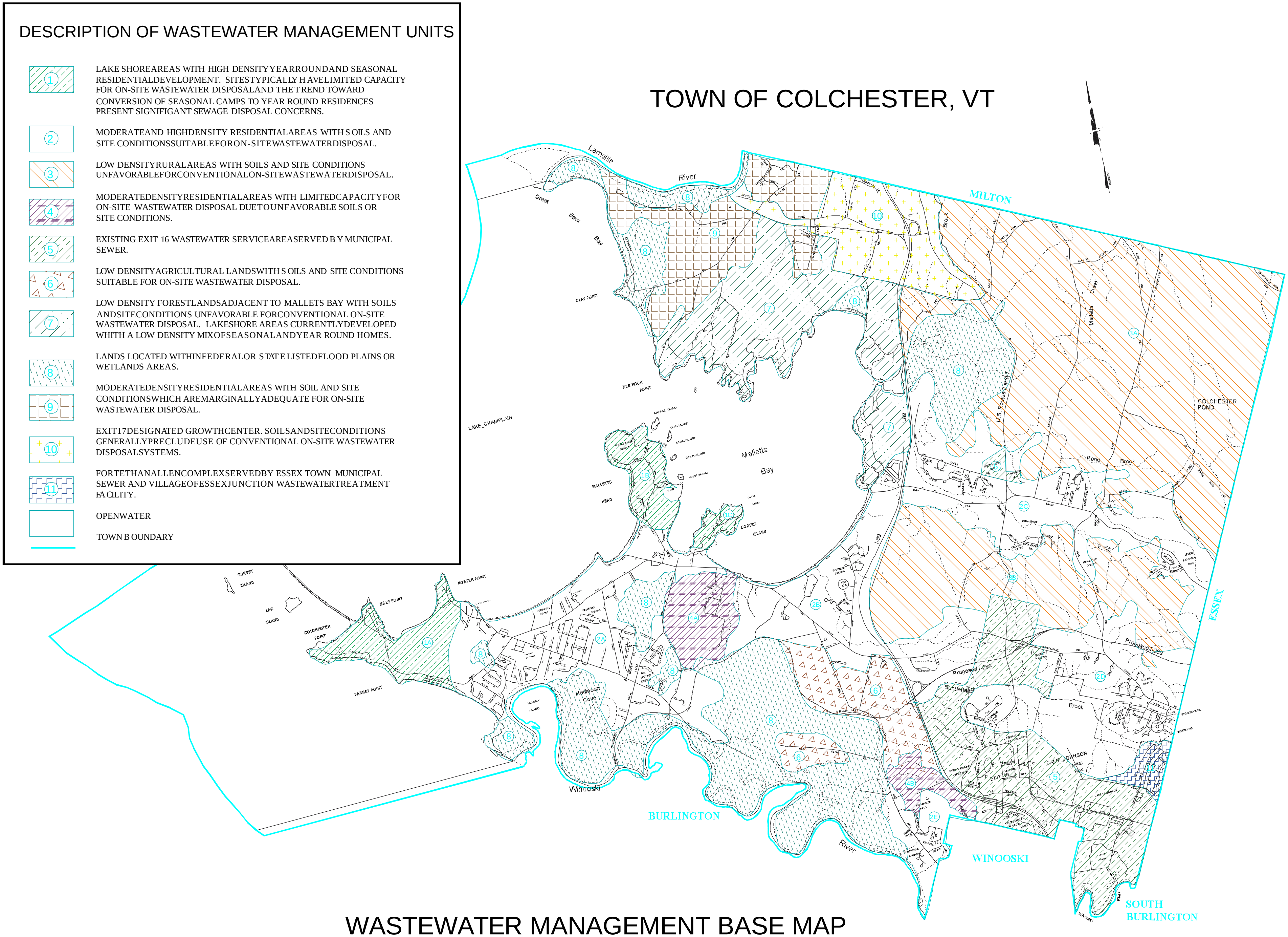

Figure 3. Wastewater management units in Colchester. Source: (Forcier Aldrich & Associates 1997).

When water is imported into an area via municipal water lines and then infiltrated on site, the additional water will raise the local water table. This can affect stream flow and other local conditions. No mention of this issue was found in the literature examined.

4.2. Stormwater

Stormwater consists of runoff during and shortly after rainfall, and a large portion generally comes from impervious areas, like roofs, roads, and parking lots. Stormwater constitutes a potential threat to water resources in three ways: 1) During a rainstorm, a higher percentage of the precipitation runs off impervious areas than pervious areas. This means that peak flows in streams are increased, which increases their erosive power or even their potential for flooding. 2) Increased runoff from impervious areas means that the water is not infiltrating into the ground to recharge the water table. This can aggravate the effects of a drought on both plants and groundwater-based drinking water supplies. 3) Stormwater can carry with it a wide range of pollutants, from lawn fertilizers and pesticides to oils, organic compounds, and metals from roads to fecal matter from domestic animals and wildlife.

No figures on the effect of stormwater on water quality in Colchester have been found. As indicated in 3.3.3, the recent stormwater plan (Griffin International 2002) rates relative degradation of subwatersheds from stormwater. An empirical indication of the effects of stormwater is found in the 2001 Water Quality Inventory Report for Malletts Bay (Foley 2001), which noted numerous cases where rainfall seemed to be followed by elevated levels of *E. coli*, in streams and even in Malletts Bay and the broad lake. No statistical analysis is presented in this report, however.

Despite the lack of firm quantification, several factors indicate that stormwater-based degradation is and will continue to be of concern in Colchester. First, there is a strong correlation between amount of developed land and the amount of phosphorus and other pollutants in the streams and rivers which flow to Lake Champlain (Lake Champlain Basin Program 2002), (Budd and Meals 1994). Second, urban runoff and land development have been identified by the Vermont DEC as possible sources of pollution in Allen Brook, Malletts Creek, and direct smaller drainages to Malletts Bay. Third, the Vermont Agency of Natural Resources has indicated that the National Pollutant Discharge Elimination System (NPDES) Phase II stormwater standards will soon be applied to the densely populated parts of Colchester (Soboslai, pers. comm.).

No description of current stormwater infrastructure has been found. In the summer and fall of 2002, the Town is performing a comprehensive inventory of the stormwater outfalls, noting their location with GPS (Global Positioning System) technology and noting properties like the condition, downstream erosion, etc. (Soboslai, pers. comm.).

4.3. Land Use

As mentioned above, the amount of developed land in a watershed correlates well with water pollution. In order to reduce this impact, Colchester has a Watercourse Protection District within 85 feet of "the center of the main channel of Allen Brook, Inidan Brook, Malletts Creek, Pond Brook and Sunderland Brook and from the center of all tributaries of the above named streams and all other minor streams" (Colchester Zoning Regulations, Sec. 301). In this buffer strip there are restrictions on building structures and on what may be done there. A buffer strip like this protects waterbodies from water pollution by providing an area where soil and plant roots can filter out some of the pollutants from stormwater. They also provide an area where rising waters encounter only vegetated soil, which slows down flooding effects and often resists erosion better than human-made structures, in the long run.

As with stormwater, no figures have been found on the effect of land use on Colchester's water quality. The following comments clarify how land use affects water quality, directly and indirectly.

Land use affects water quality directly through wastewater and stormwater impacts. Wastewater from onsite systems, if not properly treated and dispersed, can carry nutrients and pathogens to groundwater or surface water. All other things being equal, stormwater quantity increases and its quality decreases with development that increases impervious areas.

Land use, together with transportation policy, affects water quality indirectly, through the number of roads in town and car trips made. Land use patterns where houses, retail sales, and commercial areas are close together encourage short commutes and walking or cycling instead of driving. Land use clustered around a good mass transit system is another way to discourage driving. Since water quality is degraded by salt, sand, oil, gasoline, other organic compounds, and other substances that accumulate on roads, increasing roads or road use tends to decrease water quality. Increased road use by commercial vehicles also increases the danger of tanker spills of hazardous chemicals, a single one of which could severely affect water quality locally or even regionally.

While urban land contributes disproportionate amounts of polluted runoff to watersheds, the contributions from agricultural land can also be significant. Sixty six percent of the average annual phosphorus load to Lake Champlain comes from agricultural sources (Budd and Meals 1994).

4.4. Recreational Use Of Waters

No major water quality issues stemming from recreational use of waters in Colchester have been identified in the literature search. There are potential concerns. Boat motors add oil and gas to the water both during use and during fueling. Boat sewage adds pathogens and nutrients to the water, if not properly emptied at a receiving station. Boats can transport exotic, invasive species from one waterbody to another.

At a meeting conducted as part of this Strategic Water Quality Plan process, local marina representatives indicated that boat owners policed themselves pretty well now. Two or three people a year are fined for pumping their sewage overboard, mostly non-locals. A nearby island which is crowded with boaters has very clean water. And the new engines, even two-stroke engines, are much cleaner than before. As the old engines get replaced, pollution from them will be less of a problem.

Fueling remains a problem, they acknowledged, and fuel spills are “almost unavoidable.”

5. RECOMMENDATIONS

These recommendations have been drawn from the literature consulted. They are organized to roughly follow the order of the presentation above. Some of the recommendations would have an effect on more than one waterbody, but they have only been listed once. The recommendations for mitigating degradation to waterbodies also overlap some with recommendations pertinent to the specific human uses of the water.

Some of the literature consulted establishes water quality degradation without recommending actions to mitigate it, and some is comparatively heavy in recommendations. Therecommendations below have been compiled from the literature consulted, but no attempt has been made to match the number or reach of the recommendations to severity of water quality degradation in Colchester. Some of the recommendations are on a lake-wide basis for Lake Champlain and not intended for Colchester’s particular array of water quality issues.

5.1. Outer Malletts Bay

5.1.1. Nutrients

The following recommendations are quoted from the 2002 draft plan for Lake Champlain (Lake Champlain Basin Program 2002):

- Collect and analyze land use information in order to estimate the increase in phosphorus load that occurs with new development and to help target improved stormwater management to those areas experiencing the most rapid growth.
- Develop new options to offset the phosphorus load generated by new development.
- Increase efforts to reduce phosphorus loadings from new development by assisting local efforts to promote land use planning and innovative subdivision practices that discourage urban and suburban sprawl.
- Implement retrofitted stormwater management systems and other measures to reduce phosphorus loads from existing urban and suburban areas.

- Work with the state and local stormwater management programs to minimize the phosphorus load generated by new development and reduce the phosphorus load from existing areas undergoing redevelopment, including providing assistance for local compliance with USEPA Phase II stormwater rules.
- Increase training opportunities for local road supervisors and crews to encourage implementation of BMPs for road construction, repair and maintenance, according to the standards in state backroads, stormwater management, and erosion and sediment control handbooks.
- Encourage implementation of erosion and sedimentation control practices for construction activities.
- Encourage nutrient management on commercial and residential properties.

5.1.2. Toxins

The Lake Champlain Basin Program Technical Report on sediments contaminated with metals in outer Malletts Bay concludes that there is little to be done that has much effect (McIntosh, Watzin, and Brown 1997). Reducing metal inputs is one option the authors mention, though they caution, “Even with loadings reductions, changes in the bay would likely be extremely slow because of existing conditions.”

Because levels of arsenic in some portions of the bay are near the proposed federal standards for drinking water, “any use of Outer Malletts Bay for drinking water purposes needs to be carefully evaluated.”

Additional analyses of the ecological effects of arsenic and magnesium in the littoral (near-shore) sediments is recommended, following up on the toxicity on fathead minnow eggs and larvae found in this study.

Noting that zebra mussels in large numbers could mobilize more toxic metals from the sediment, the authors recommend “that this concern be addressed as the zebra mussel invades Outer Malletts Bay in large numbers.” It is unclear how they wish the concern to be addressed.

5.1.3. Invasive Species

No recommendations appropriate for action at the town level were found in the literature. The Lake Champlain Basin Program web site (http://www.anr.state.vt.us/champ/action.htm#nuistips) recommends actions for individuals. Education around the quoted actions could be the basis of a local program:

- Each time a boat or other item is used in water bodies infested by zebra mussels or other nuisance aquatic species, the boat, trailer, and equipment should be carefully inspected for evidence of these species. Remove any mussels or vegetation and dispose of them in the trash.

- Drain all water from the boat, including the bilge, live well, and engine cooling system.
- Dry the boat and trailer in the sun for at least five days, or if you use your boat sooner, rinse off the boat, trailer, anchor, anchor line, bumpers, engine, etc. with hot water or at a car wash.
- Leave live aquatic bait and bait used in infested waters behind- either give it to someone using the same water body, or discard it in the trash.
- When recreating in areas infested with Eurasian watermilfoil, be careful not to break apart the plant since milfoil spreads by plant fragments.
- Contact the Vermont Department of Environmental Conservation, the Lake Champlain Basin Program, and the New York Department of Environmental Conservation to find out how to become involved in monitoring and outreach activities to help prevent the spread of nuisance nonnative aquatic species in the Lake Champlain Basin.

5.1.4. Other

For esocid lymphosarcoma in muskellenge and northern pike, no recommendations were found for action, other than that individuals refrain from eating the fish with tumors.

5.2. Inner Malletts Bay

The following list of recommendations is drawn from several years of reports by the Town's Water Quality Coordinators. Recommendations already acted on have been omitted:

- The Town should develop a septic maintenance ordinance and septic system management program
- The Town should have stronger enforcement of leash laws and pooper scooper laws, with signs to explain why this is being done.
- Investigate better ways to manage stormwater (use "low impact development")
- "Wish list" studies include:
  - Inventory of streams to Malletts Bay, using a variety of biological, chemical, and physical parameters to monitor health
  - Land use study of human impacts in entire watershed, or at least impacts adjacent to watercourses
- Education
  - Pamphlets and/or signs to educate people on problems caused by feeding ducks, placed adjacent to Malletts Bay and marinas
  - Public education about non-point source pollution. In particular, more educational outreach to homeowners about individual practices and their effect on the lake: particularly runoff.
- Since beach closures coincide closely with rain events, use rain to pose advance warning of beach closings before the results of fecal coliform tests are available, which takes around 27 hours after sampling. (This could mean either warning people of increased risk without closing the beach or risking closing the beach when fecal coliform limits not exceeded.)

- Install a riparian buffer strip for Bayside Beach.

5.3. Rivers and Streams

Among the recommendations in the current draft of the Lake Champlain Basin Program's plan for the lake (Lake Champlain Basin Program 2002), the following are directly relevant for rivers and streams:

- Expand programs for streambank restoration and the installation of vegetated buffer areas along eroding streams and rivers

Studies have shown that vegetated areas along streams and rivers can effectively filter sediment and phosphorus from runoff and reduce streambank erosion, while creating habitat for wildlife. Stream geomorphology concepts can be used to determine where and how to address problems with erosion so that the entire stream system remains more stable over time.

a) Use geomorphic assessment and other techniques to target reaches where significant phosphorus loading may be occurring as a result of erosion.
b) Develop or expand programs which cost share or offer tax incentives for voluntary restoration or protection of buffer strips on perennial streams, rivers and lakes in the Basin.
c) Develop a GIS database of reaches needing buffer areas for use by programs such as the NY and VT Conservation Reserve Enhancement Program (CREP) and the USDA Environmental Quality Incentives Program (EQIP)....
f) Increase programs aimed at informing professionals working on streams (e.g., municipal officials, landscape architects, etc.) about the value and importance of buffers and stable streams.
g) Identify additional funding sources for streambank restoration.

- Develop Incentives for Local Municipalities and Private Land owners to Restore, Enhance and Maintain Wetlands and Stream Corridors.

Tax incentives are another way to encourage private wetlands and stream protection and restoration efforts. Under this option, a task force could be established to develop legislation to alleviate part of the tax burden for landowners who practice habitat conservation.

- Increase funds and technical resources for local governments to implement BMPs for new development which will protect wetlands, stream corridors and riparian habitat

Encourage local governments to:
a) Improve stormwater management through local zoning and subdivision regulation and appropriate use of the National Pollutant Discharge Elimination System (NPDES) and State Pollution Discharge Elimination System (SPDES) permit system, including EPA Phase 2 stormwater regulations.
b) Emphasize erosion hazards, floodplain functions, sedimentation controls, habitat protection and use of natural vegetation as requirements in local zoning and subdivision regulations.
c) Apply infiltration and other BMPs in new developments.
d) Apply surface water setbacks and buffer strips in new developments.
e) Employ appropriate growth management options.
f) Assess cumulative impacts of new development.
g) Promote innovative site design that reduces creation of impervious surfaces.
h) Promote road maintenance standards for sediment control and initiate training programs for town highway departments to minimize impacts of road maintenance activities on water quality, streambank stability and native wetland species.

5.4. Wastewater

The 1997 wastewater facility plan update makes a number of detailed recommendations for each wastewater management unit. The recommendations are based on a screening analysis, using nine criteria. Weights were assigned to the criteria in cooperation with Town staff and the Colchester Wastewater Management Steering Committee. Consequently, the recommendations may no longer represent today's needs, if preferences of today's townspeople are different than those of the Town staff and the Wastewater Management Steering Committee at the time this weighting was done. Nonetheless, the most general recommendations are presented here:

- The Town should consider more stringent design and construction standards for onsite wastewater systems.
- The Town should implement an expanded onsite wastewater management program.

5.5. Stormwater

The recent stormwater management plan (Griffin International 2002) contains recommendations for best management practices (BMPs) to use in each subwatershed. These are too detailed to be included here; the reader is referred to pp. 61-72 of that report. Non-structural BMPs recommended for the town as a whole are:

- revision of town zoning laws
- update of highway codes
- public education initatives
- town programs unspecified

In addition, the following non-structural BMPs are recommended for many of the subwatersheds:

- ending illicit connections and discharge
- stormwater credits (non-structural BMPs used on a new construction site reduce the requirement for structural BMPs)

A stormwater ordinance has also been drafted for the Town's consideration. The consulting team says that it "will satisfy a significant portion of the requirements of the EPA NPDES Phase II Stormwater Regulations."

5.6. Land use

The current draft of the Lake Champlain Basin Program's plan for the lake (Lake Champlain Basin Program 2002) calls for estimating "the nonpoint source phosphorus load that is being generated by developed land uses (urban and suburban land, roads, etc.) in the basin and work[ing] aggressively to reduce this load." The plan continues:

> Based on an LCBP analysis in 2000, it appears that increased phosphorus loads generated by land use changes in the Basin are offsetting some of the gains achieved by point and agricultural nonpoint source reduction efforts. Other studies have shown

> that developed land typically contributes more phosphorus per unit area of land than other land use types. As the population within the Basin increases, there is the opportunity to encourage growth away from the land-intensive suburban sprawl-type development and to better manage the resulting polluted urban storm water to minimize increases in phosphorus loads to the Lake.

The work put into the Strategic Water Quality Plan will be important to the land-use decisions in Colchester, according to the present Draft Master Plan (Town of Colchester Vermont, 2001):

> Planning should drive infrastructure (as opposed to available infrastructure determining planning). As soon as the Water Quality Committee makes its recommendations to the Town, Colchester needs to review its plans for utilities, facilities, and services to ensure they are compatible and coordinated with any recommendations.

5.7. Recreational Use of the Waters

No specific recommendations for reducing impact from recreational use of the receiving waters were found in the literature consulted.

6. CONCLUSION

This report has, on the basis of a number of studies consulted, identified water resources in Colchester, degradation they exhibit, and the impact of specific human activities on the water resources. It has also presented selected recommendations for actions to maintain and improve water quality.

No one report or study attempts to prioritize these water resources according to their value to the town or townspeople or to prioritize recommendations for actions to improve Colchester's water quality. The Lake Champlain action plan (Lake Champlain Basin Program 2002) does prioritize its recommendations in various categories of action, but priorities for Lake Champlain may not directly translate into priorities for Colchester.

The Strategic Water Quality planning process will identify tasks for closer examination, and townspeople will be given the opportunity to prioritize them. These priorities will emerge out of public meetings and other input processes, which Colchester's Water Quality Committee will use to set priorities for the future. We hope that this report will prove useful in that process.

7. REFERENCES

Associated Press. 2002. Lake Champlain pike may have viral disease. *Times Argus*.

Bress, Bill. Personal communication. 30 April 2002.

Budd, Lenore F., and Donald W. Meals. 1994. Lake Champlain nonpoint source pollution assessment: Lake Champlain Basin Program.

Center for Rural Studies. 2002. *Socioeconomic Indicators for Vermont Communities* [web page]. Center for Rural Studies at University of Vermont, February 3, 1998 1998 [cited June 25, 2002 2002]. Available from access through http://crs.uvm.edu/indicators/chittend.htm.

Dion, Tom. Personal communication, 25 June 2002. Burlington Department of Public Works.

Fay, Jim. Personal communication, 28 June 2002. Champlain Water District.

Foley, Peter. 2001. Malletts Bay Water Quality Inventory Report: Summer 2001. Colchester, Vermont: Town of Colchester, Vermont.

Forcier Aldrich & Associates. 1997. Town of Colchester wastewater master planning Part II: Town-wide wastewater facility planning update. Vol. 1. Essex Junction, Vermont: Forcier Aldrich & Associates.

Gabos, Ben. 2000. Malletts Bay Water Quality Inventory Report: Summer 2000. Colchester, Vermont: Town of Colchester, Vermont.

Griffin International. 2002. Town of Colchester municipal stormwater management plan. Williston, Vermont: Griffin International,.

Jones, Stephen H. 2002. Microbial source tracking in Vermont using ribotyping of Escherichia coli isolates. Durham, New Hampshire: Jackson Estuarine Laboratory, University of New Hampshire.

Jones, Stephen H. Personal communication. 1 July 2002.

Lake Champlain Basin Program 2000. *Lake Champlain Fish Advisory*. Lake Champlain Basin Program, 15 August 2000 [cited 30 April 2002. Available from http://www.anr.state.vt.us/champ/fishadvs.htm.

———. 2002. Opportunities for action: An evolving plan for the future of the Lake Champlain basin (DRAFT): Lake Champlain Basin Program.

McIntosh, Alan, Mary Watzin, and Erik Brown, eds. 1997. *An assessment of sediment-associated contaminants in Lake Champlain - Phase II*, *Lake Champlain Basin Program Technical Reports*: Lake Champlain Basin Program.

Moulaert, April. Personal communication. Vermont Department of Environmental Conservation. 26 June 2002.

Nashett, Lawrence J., Jon K. Anderson, Brian D. Chipman, Lance E. Durfey, John E. Gersmehl, Shawn P. Good, Madeleine M. Lyttle, Chet MacKenzie, J. Ellen Marsden, Donna L. Parrish, David C. Nettles, Nick R. Staats, and Lawrence E. Strait. 1999. A comprehensive evaluation of an eight year program of sea lamprey control in Lake Champlain: Fisheries Technical Committee of the Lake Champlain Fish and Wildlife Management Cooperative.

National Wetland Inventory. *Database query: number and area of wetlands in Colchester* [Database]. National Wetland Inventory n.d.

Program, Lake Champlain Basin. *Lake Champlain Interim Total Phosphorus Criteria and Existing Phosphorus Concentrations* [Web page]. Lake Champlain Basin Program, 10 June 1998 1998 [cited 30 April 2002. Available from http://www.anr.state.vt.us/champ/phostab1.htm.

Smeltzer, Eric, and Scott Quinn. 1996. A phosphorus budget, model, and load reduction strategy for Lake Champlain. *Journal of Lake and Reservoir Managemetn* 12 (3):381-393.

Soboslai, Genie. Department of Public Works, Town of Colchester. Personal communications. June 26, 2002; July 18, 2002.

Town of Colchester Vermont. 2001. Town of Colchester Master Plan (Draft). Colchester, Vermont: Colchester Select Board

Colchester Planning Commission.

Vermont Department of Environmental Conservation. Colchester water quality report: Vermont Department of Environmental Conservation.

Water Quality Division, Vermont Department of Environmental Conservation. 2002a. Draft list of priority surface water outside the scope of Clean Water Act Section 303(d). Waterbury, Vermont: Water Quality Division, Vermont Department of Environmental Conservation.

Water Quality Division, Vermont Department of Environmental Conservation. 2002b. Draft 303(d) list of waters. Waterbury, Vermont: Water Quality Division, Vermont Department of Environmental Conservation

APPENDIX (ANNOTATED BIBLIOGRAPHY)